

# Outline of Diesel Retrofit Program in Japan

International Diesel Retrofit Advisory Committee Meeting  
June 5, 2001

**Matsuo Odaka**  
**National Traffic Safety and Environment Laboratory**  
**Japan**

## CONTENTS

### **1. Background**

- Use of Motor Vehicles
- State of Air Pollution

### **2. Policy for Motor Vehicle Exhaust Emission Reduction Measures**

- Exhaust Emission Regulations for Newly made Diesel Vehicles
- Automobile NOx Control Law
- Measures for In-use Diesel-powered Vehicles

### **3. DPF Evaluation Program**

- Emission Reduction Performance
- Regeneration Performance
- Durability

### **4. Examples of Failure during Evaluation Test**

### **5. Policy of Japanese Government for Diesel Retrofit**

## **BACKGROUND**

the growth in the economy (started around 1955)  
Resulting in rapid motorization.



motor vehicle exhaust emissions have been  
causing serious social and environmental  
problems in Japan.

## **Use of Motor Vehicles**

### **Number of vehicles**

3.4 million in fiscal 1955

73 million in fiscal 1997

passenger cars

About 0.49 million in fiscal 1955 (14.5% )

About 48.68 million in fiscal 1997 (66.8%)

### **Ratio of transportation volume by motor vehicles**

Freight:15% in fiscal 1960

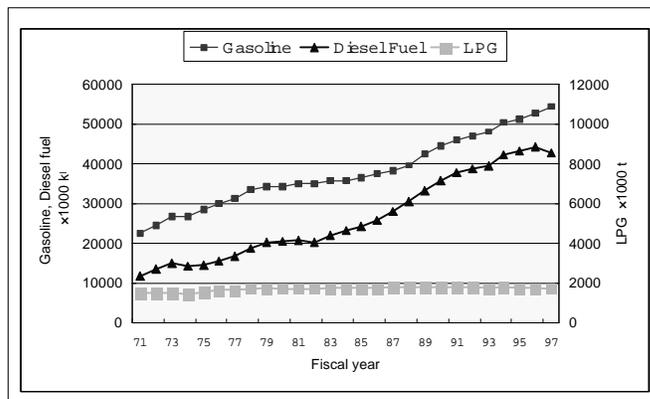
39% in fiscal 1972

53% in fiscal 1996

Passenger:23% in fiscal 1960

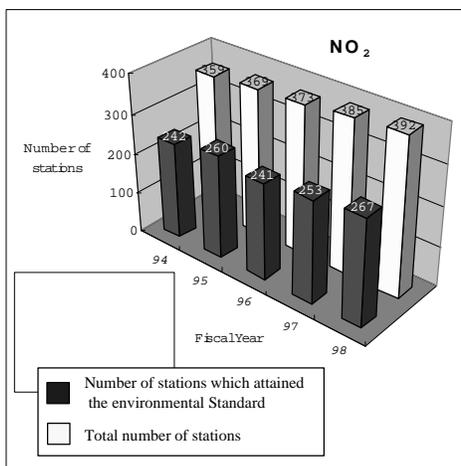
51% in fiscal 1972

60% in fiscal 1996



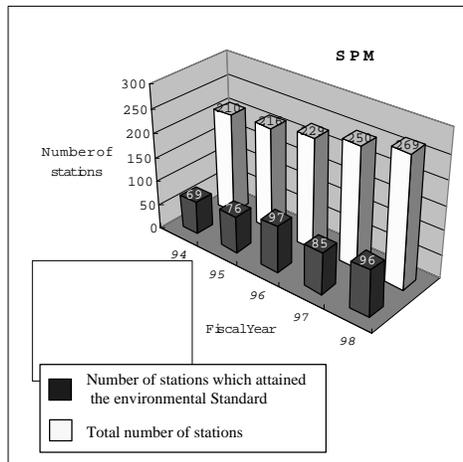
- In fiscal 1971, gasoline accounted for 22.398 million k<sub>l</sub>; diesel fuel, 11.658 million k<sub>l</sub> and LPG, 1.491 million tons. However, in fiscal 1997, these figures increased to 54.221 million k<sub>l</sub>, 42.750 million k<sub>l</sub> and 1.709 tons, respectively.
- Fuel consumption decreased in the period from fiscal 1973 to fiscal 1974 due to the oil crisis, since then the trend shows a steady increase.

### State of Air Pollution (NO<sub>2</sub>)



- In fiscal 1997, 253 road side air pollution monitoring stations (65.7%) out of 385 attained the environmental quality standard for NO<sub>2</sub> concentration.
- The attainment rate increased compared with fiscal 1996, when 241 stations (64.6%) out of 373 met the standard.
- However, the trend in attainment rate has been flat at about 65% in recent years, which means the state is still severe.
- fiscal 1994: 32% of Total NO<sub>x</sub> emissions were from automobiles (estimated 806,000 tons).

## State of Air Pollution (PM)



- In fiscal 1997, the number of roadside air pollution monitoring stations which attained the quality standard for SPM was 85 out of 250 (34.0%). The attainment rate decreased compared with fiscal 1996, when 97 roadside stations out of 229 (42.4%) met the standard. The situation is still severe.

- The annual average value of SPM at 101 roadside air pollution monitoring stations has slightly decreased over the past ten years.

- However, a high level of concentration is still registered.

## MOTOR VEHICLE EXHAUST EMISSION REGULATIONS

- **The Air Pollution Control Law. (Ministry of Environment)**

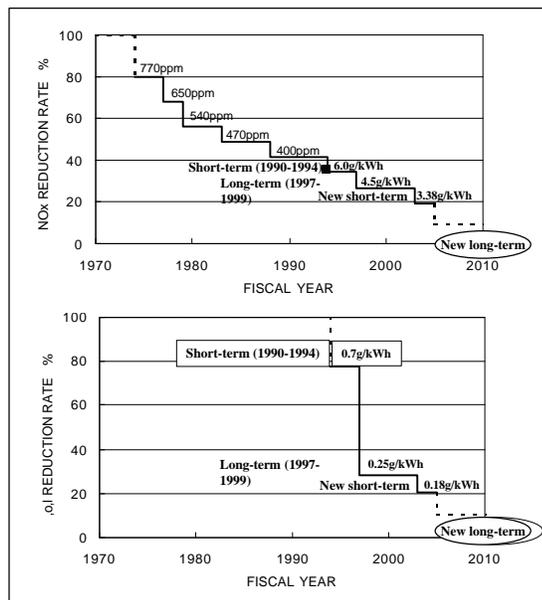
permissible limits on the amounts of motor vehicle exhaust emissions

- **The Road Vehicle Act (Ministry of Land, Infrastructure and Transport )**

matters necessary for vehicle exhaust emission regulations by means of the safety regulations for road vehicles to ensure that these permissible limits are met

## Reduction of exhaust emissions from diesel powered vehicles:

Vehicle Category	Test method (Unit)	Component	Current regulation		New short-term target			New long-term target	
			Enforcement year	Regulation Value	Enforcement year	Target Value	Reduction rate		
<b>Passenger cars</b>									
Small-sized vehicles (1.25t or less)	10-15 mode (g/km)	NOx	(1997)	0.40	(2002)	0.28	30%	Technological development is promoted to reduce the exhaust emissions about half the new short-term target values by around 2007	
		PM		0.08		0.052	35%		
		HC	(1986)	0.40		0.12	70%		
		CO		2.10		0.63	70%		
Medium-sized vehicles (over 1.25t)	10-15 mode (g/km)	NOx	(1998)	0.40	(2002)	0.3	25%		
		PM		0.08		0.056	30%		
		HC	(1986)	0.40		0.12	70%		
		CO		2.10		0.63	70%		
<b>Trucks / Buses (Medium-duty vehicles)</b>									
1.7t or less	10-15 mode (g/km)	NOx	(1997)	0.40	(2002)	0.28	30%	Specific target values target time of achievement etc. will be decided by the end of fiscal 2002.	
		PM		0.08		0.052	35%		
		HC	(1988)	0.40		0.12	70%		
		CO		2.10		0.63	70%		
<b>Trucks / Buses (Medium-duty vehicles)</b>									
Over 1.7t to 2.5t incl.	10-15 mode (g/km)	NOx	(1997/1998)	0.70	(2003)	0.49	30%	Target reduction rates relative to the regulation values for 1997, 1998 and 1999 Regulations are as follows:	
		PM		0.09		0.06	33%		
		HC	(1993)	0.40		0.12	70%		
		CO		2.10		0.63	70%		
<b>Trucks / Buses (Heavy-duty vehicles)</b>									
Over 2.5t to 12t	D-13 mode (g/kWh)	NOx	(1997/1998)	4.50	(2003)	3.38	25%	NOx: a limit over 60%	
		PM		0.25		0.18	28%		
		HC	(1994)	2.90		0.87	70%		
		CO		7.40		2.22	70%		
Over 12t	D-13 mode (g/kWh)	NOx	(1994)	(D) 6.00 (H) 5.00	(2004)	3.38	44%	PM: a limit over 60%	
		PM	(1999)	4.50		2.5%			
		HC	(1994)	0.70		0.18	74%		HC: a limit over 80%
		CO	(1999)	0.25		0.87	70%		CO: a limit over 80%
		CO	(1994)	7.40		2.22	70%		



**Note:**  
 The values shown for the period when no regulation existed for emission control are estimates.  
 The regulation for NOx was changed from concentration (ppm) control to weight (g/kWh) control in 1994  
 The control values in the new long-term regulation is specified at about 1/2 that in the new short-term regulation.

**Trend of NOx and PM Control Values**

## **Reduction of exhaust emissions from diesel powered vehicles**

### **Diesel emission regulations are to be tightened in two steps**

#### 1) New short-term target.

For passenger cars, trucks, and buses, during 2002 to 2004, all exhaust emission components subject to regulations are to be reduced by about 30% to 70% from the current regulation level.

#### 2) New long-term target.

For all categories of vehicles, emission control technology is to be developed with the aim of reducing exhaust emissions to about half the new short-term target values by 2005.

Regarding the diesel fuel quality required to achieve the new long-term target values, the required fuel sulfur content will be reduced to 50 ppm by the end of fiscal 2004.

## **Automobile NOx Control Law**

●The levels of air pollution caused by NOx around major urban areas remain significant because of the increase in traffic volume and in the number of diesel-powered vehicles.

●“Law concerning Special Measures for total Emission Nitrogen Oxides from Automobiles in Specified Areas” (Automobile NOx Law) was enacted in June 1992.

### **Special NOx emission standard**

●A special NOx emission standard has been introduced for designated diesel powered vehicles (trucks and buses, etc., which are registered in the specified areas).

●This standard will apply not only to new automobiles, but also, after a certain grace period to automobiles already in use.

●Designated vehicles not complying with the standard cannot be newly registered in the specified areas.

●In-use vehicles, which are not complying with the standard will not be approved at the time of inspection and thereafter will not be allowed in use.

●It becomes necessary for those vehicles to be replaced with vehicles which have less emission of NOx and meet the standard.

### **Automobile NO<sub>x</sub> Control Law (continued)**

June 1st, 2001

An amendment of Automobile NO<sub>x</sub> Control Law was approved in the Upper House.

PM is added as pollutant and diesel passenger car is included as “designated diesel powered vehicles”.

The specified areas are also expanded.

### **Measures for In-use Diesel-powered Vehicles**

#### Background

●January 31, 2000: The Kobe District Court acknowledged the relationship between asthma of the plaintiffs and SPM, especially DEP. The court also ruled that the government and Hanshin Expressway shall keep the SPM concentration level lower than 0.15mg/m<sup>3</sup> within 50m from the roadside of both roads.

●February 18, 2000: The Tokyo Metropolitan Government announced draft regulations for the mandatory installment of diesel particulate filters (DPF) for all diesel vehicles in the Tokyo area.

The draft regulations will be enforced from April 2003, beginning with older vehicles. All diesel-powered vehicles without a DPF will be prohibited in Tokyo after April 2006.

## Government activity for evaluation of diesel exhaust countermeasure technologies

- DPFs have a certain capability to reduce PM from diesel-powered vehicles.
- However, there are some problems yet to be solved, such as cost and durability, before widely introducing DPFs in Japan.

### study group for evaluation of diesel vehicle countermeasure technologies

(jointly established by Environment Agency, MITI, Ministry of Transport )

With respect to countermeasures against emissions from in-use diesel-powered vehicles, The study group has been examining such things as performance in reducing diesel vehicle emissions and durability.

## DPF Evaluation Program

	Alternate regenerative type DPF		Continuous regenerative type DPF (a) (based on oxidation by NO <sub>2</sub> )		
Performed by	Tokyo Metropolitan Government (some tests commissioned to Environment Agency)	JCAP	Environment Agency	JCAP	Tokyo Metropolitan Government (TMG)
Fuel	Existing diesel fuel	Existing diesel fuel	Low-sulfur diesel fuel	Existing diesel fuel/low-sulfur diesel fuel	Low-sulfur diesel fuel

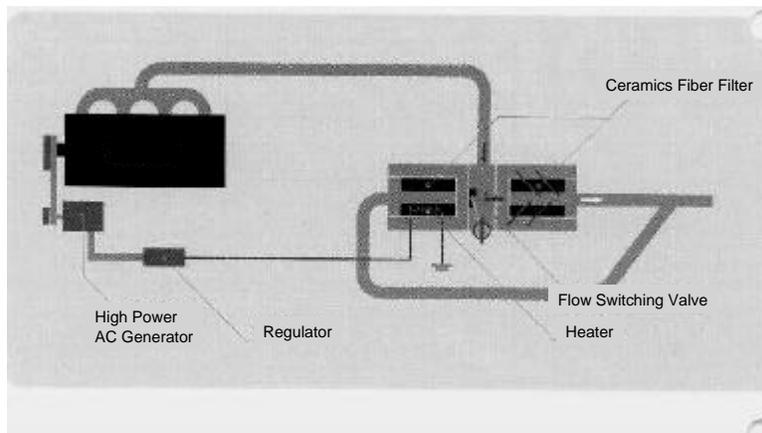
### DPF Evaluation Program (Continued)

	Alternate regenerative type DPF		Continuous regenerative type DPF(a) (based on oxidation by NO <sub>2</sub> )		
	Exhaust emission test 2-ton trucks (vehicles conforming to short-term regulation) 4-ton trucks (vehicles conforming to 1989 regulation) 14-ton trucks (vehicles conforming to short-term regulation) Road test Buses/trucks etc.(53 units)	Exhaust emission test Engines conforming to 1989 regulation	Exhaust emission test 6-ton truck (vehicles conforming to long-term regulation) 16-ton trucks (vehicles conforming to short-term regulation)	Exhaust emission test Engines conforming to 1989 regulation Engines conforming to short-term regulation Engines conforming to long-term regulation	Exhaust emission test Bus (1 unit) (vehicle conforming to short-term regulation)
Category of motor vehicles					

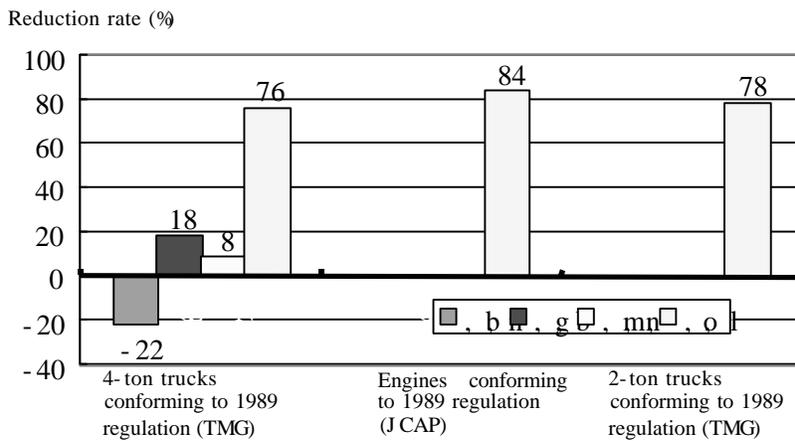
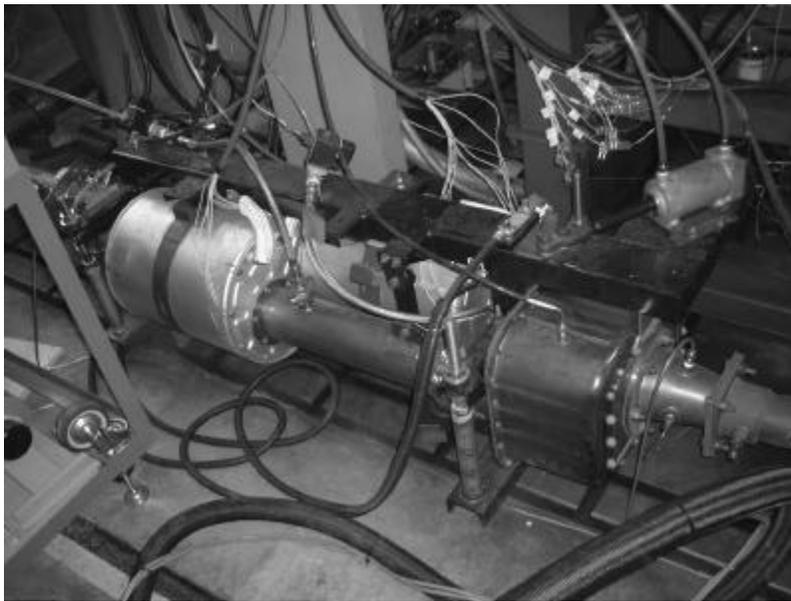
### DPF Evaluation Program (Continued)

	Continuous regenerative type DPF (b) (based on oxidation by catalyst)		
Performed by	Ministry of Transport / Japan Trucking Association	JCAP	Tokyo Metropolitan Government (TMG)
Category of motor vehicles	Exhaust emission test Engines conforming to short-term regulation (2 units) 10-ton trucks (vehicles conforming to short-term regulation) 4-ton trucks (vehicles conforming to 1989 regulation) Road test Trucks (15 units)	Exhaust emission test Engines conforming to 1989 regulation Engines conforming to short-term regulation Engines conforming to long-term regulation	Exhaust emission test 8-ton trucks (vehicles conforming to 1989 regulation) Buses vehicles conforming to 1989 regulation)
Fuel	Existing diesel fuel	Existing diesel fuel low-sulfur diesel fuel	Existing diesel fuel

- Alternate Regenerative Type DPF

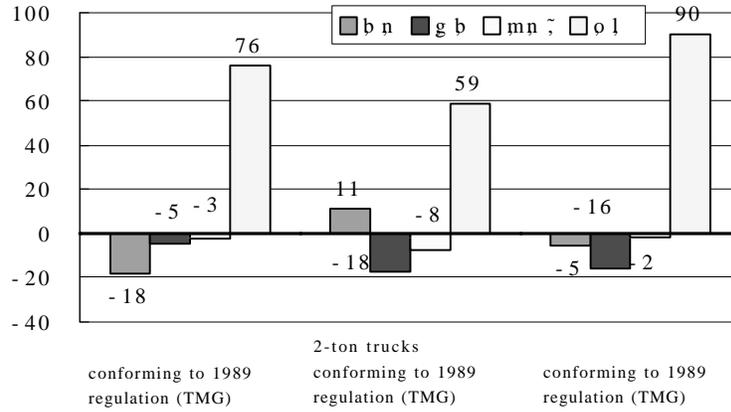


Alternate Regenerative Type DPF (developed by ISUZU Co.Ltd)



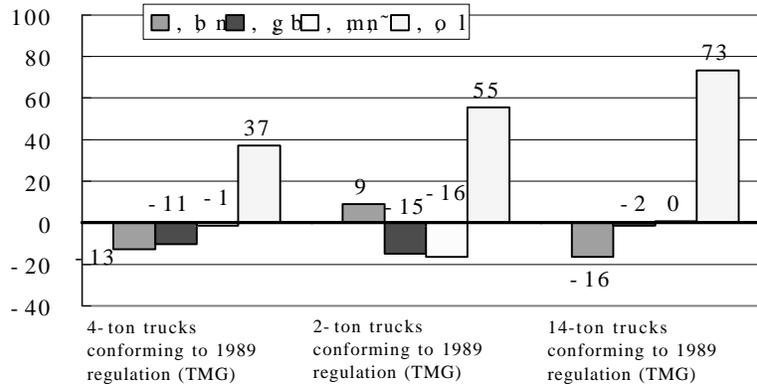
Exhaust Emission Test Results of Alternate Regenerative Type DPF (D13-mode: using existing diesel fuel) trucks conforming to 1989 regulation (TMG)

Reduction rate (%)

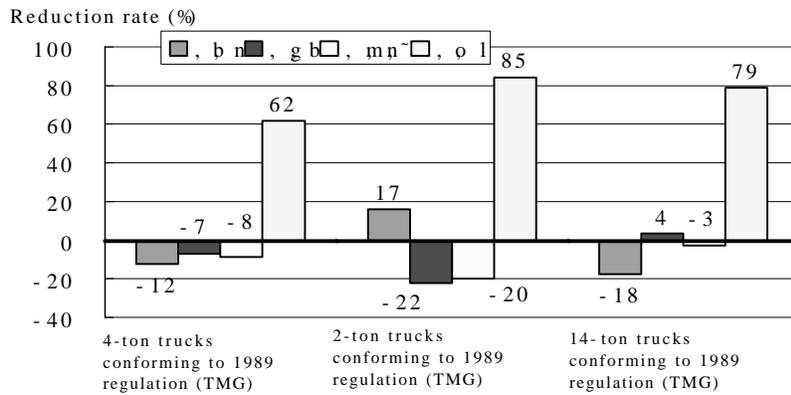


Exhaust Emission Test Results of Alternate Regenerative Type DPF (actual running mode (average speed 8.4 km/h): using existing diesel fuel)

Reduction rate (%)



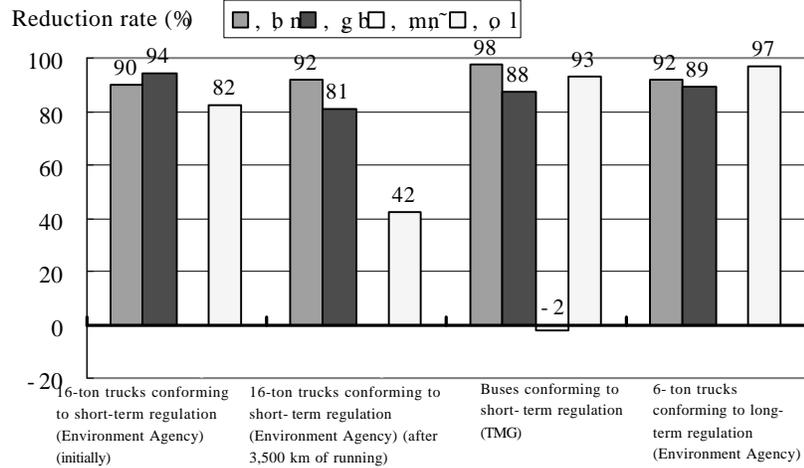
Exhaust Emission Test Results of Alternate Regenerative Type DPF (actual running mode (average speed 18 km/h): using existing diesel fuel)



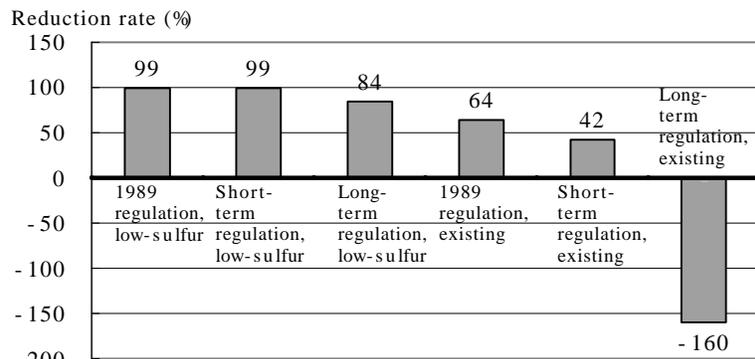
Exhaust Emission Test Results of Alternate Regenerative Type DPF (actual running mode (average speed 28.5 km/h): using existing diesel fuel)

## Continuously Regenerating Type DPF(a)

- Based on oxidation by  $\text{NO}_2$  -

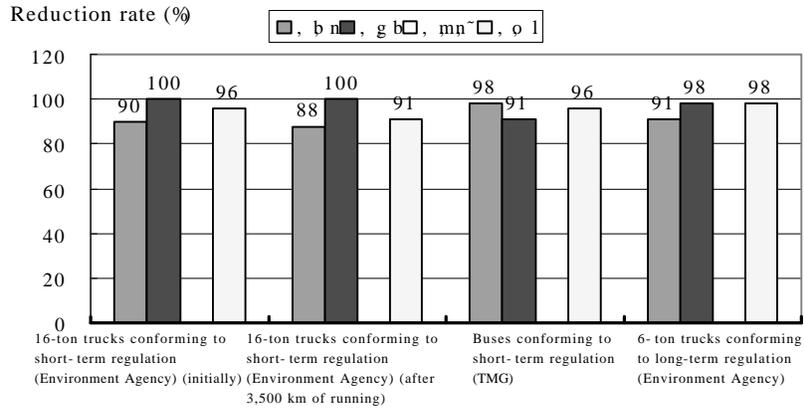


Exhaust Emission Test Results of Continuous Regenerative Type DPF (a) (D13-mode: using existing diesel fuel)

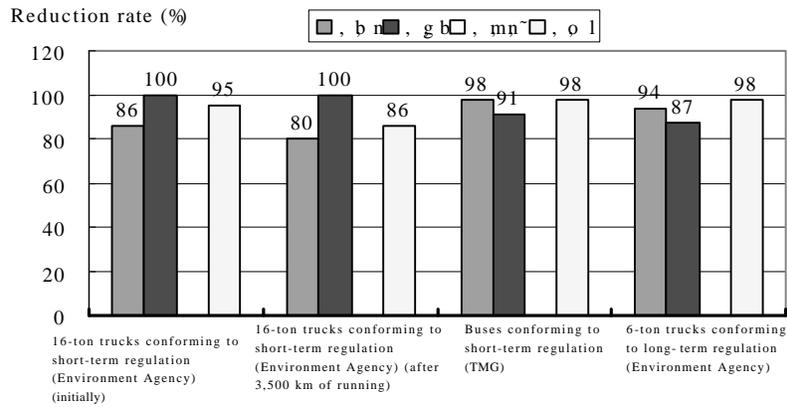


Note: Low-sulfur and existing mean low-sulfur diesel fuel (46 ppm) and the existing diesel fuel (443 ppm) used in tests, respectively.

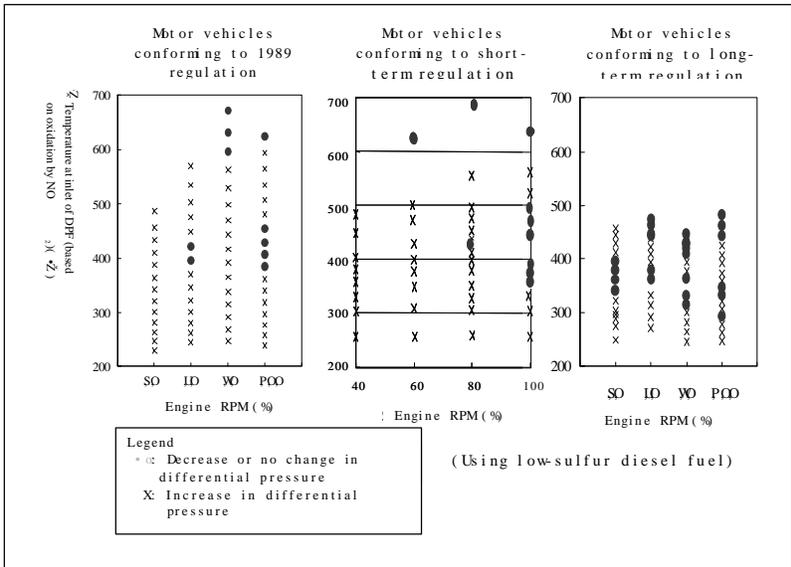
PM reduction rate of Continuous Regenerative Type DPF (a) (D13-mode: change in sulfur content)



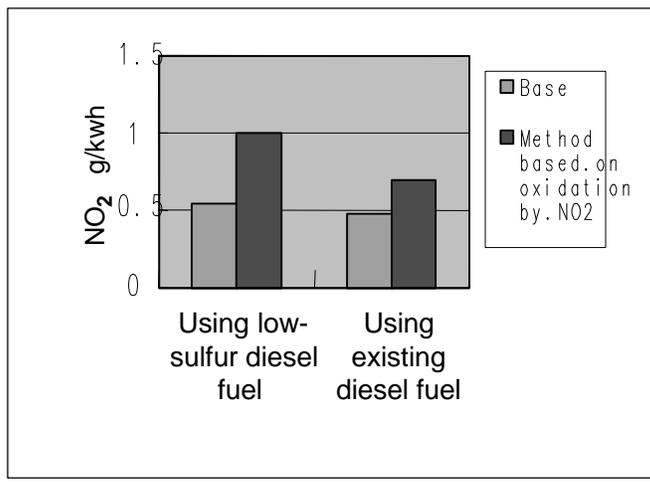
Exhaust Emission Test Results of Continuous Regenerative Type DPF (a) (actual running mode (15.2 km/h): using low-sulfur diesel fuel) (average speed 17.9 km/h for Tokyo metropolitan buses only)



Exhaust Emission Test Results of Continuous Regenerative Type DPF (a) (actual running mode (average speed 45 km/h): using existing diesel fuel) (average speed 44.2 km/h for Tokyo metropolitan buses only)



Regeneration Temperature Ranges (using low-sulfur diesel fuel)



Effects of Installed DPF (a) on the Amount. of NO<sub>2</sub> Emissions

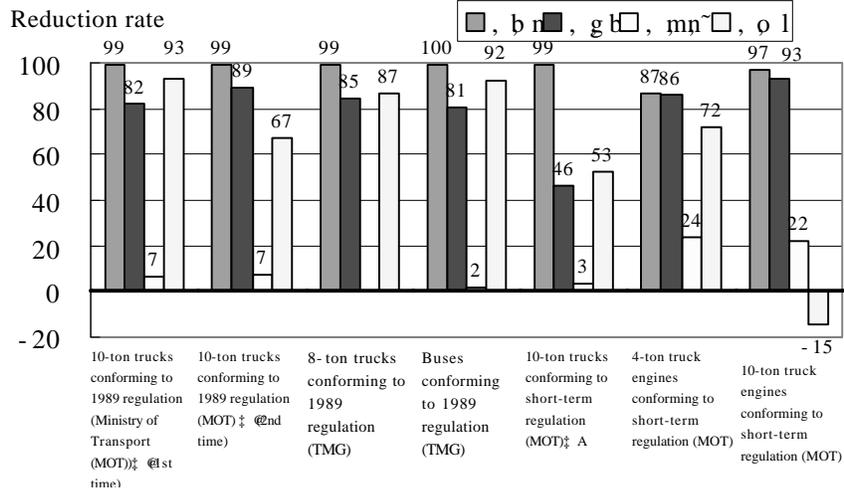
## Continuously ● Regenerating Type DPF (b)

- Based on oxidation by catalyst -

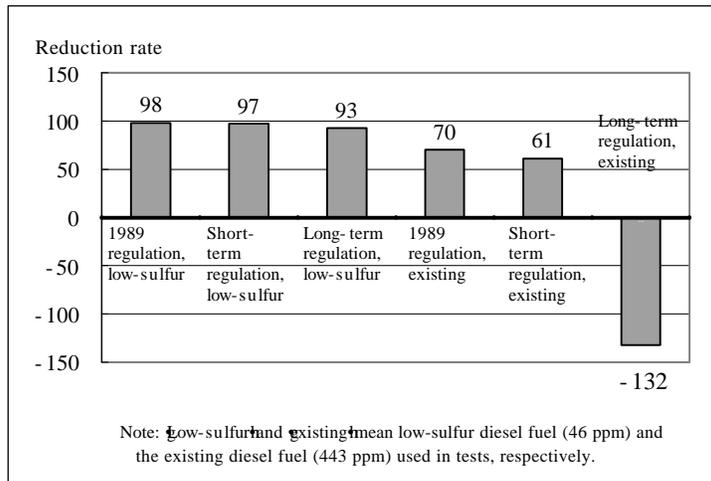
### Test Driving Cycle

	Driving mode	mark	Average Speed (km/h)	note
Chassis Test Mode	TMG No.2	...	8.4	
	TMG No.5	...	17.9	
	TMG No.8	...	28.5	
	TMG No.12	....	53.3	
	MOT M15 mode	...	15	
Engine Test Mode	... mode	...		Steady-state mode
	FTP 1199	1199		
	. T. mode	...		
	.... engine test mode	....		Used for regeneration performance test

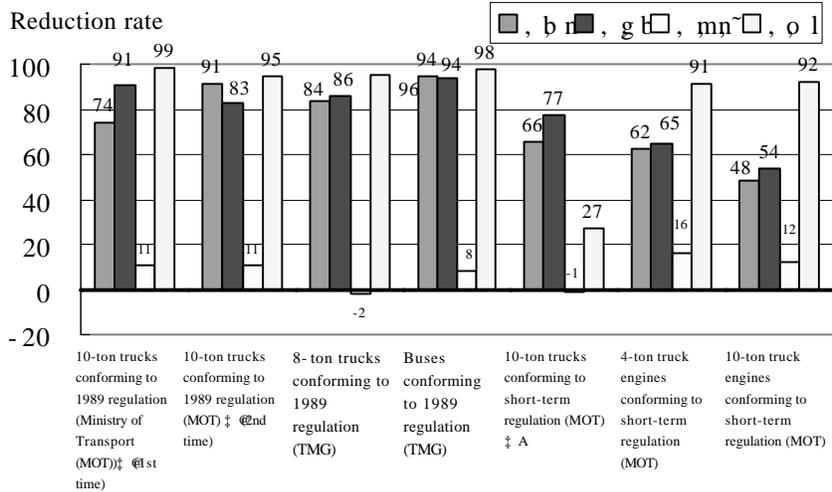
\* TMG: Tokyo Metropolitan Government



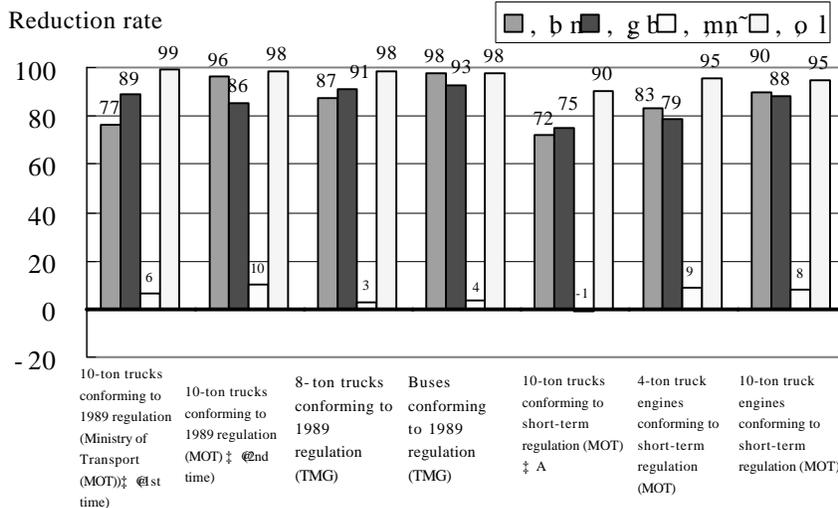
Exhaust Emission Test Results of Continuous Regenerative Type DPF (b) (D13-mode: using existing diesel fuel)



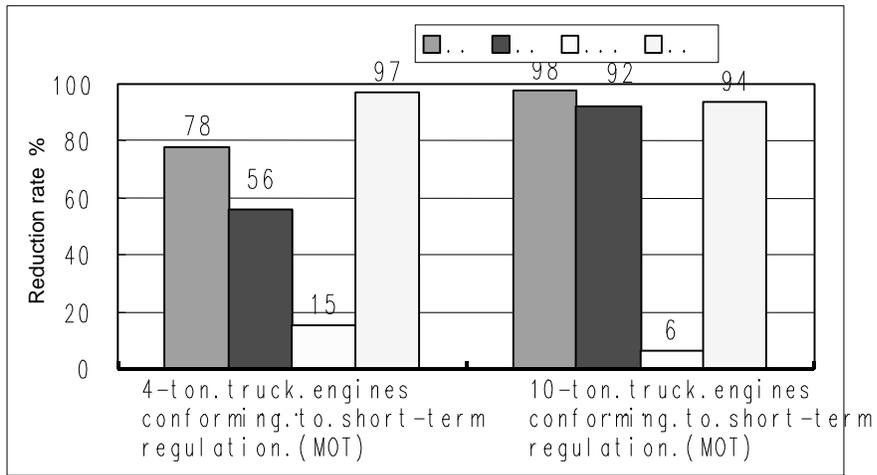
PM reduction rate of Continuous Regenerative Type DPF (b) (D13-mode, change in sulfur content)



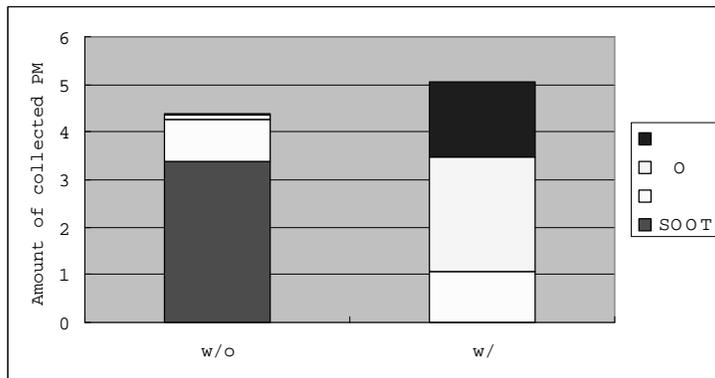
Exhaust Emission Test Results of Continuous Regenerative Type DPF (b) (actual running mode (average speed 8.4 km/h): using existing diesel fuel)



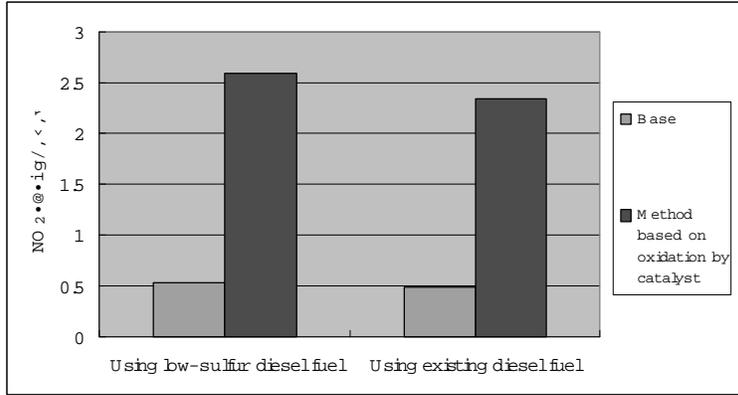
Exhaust Emission Test Results of Continuous Regenerative Type DPF (b) (actual running mode (average speed 18 km/h): using existing diesel fuel)



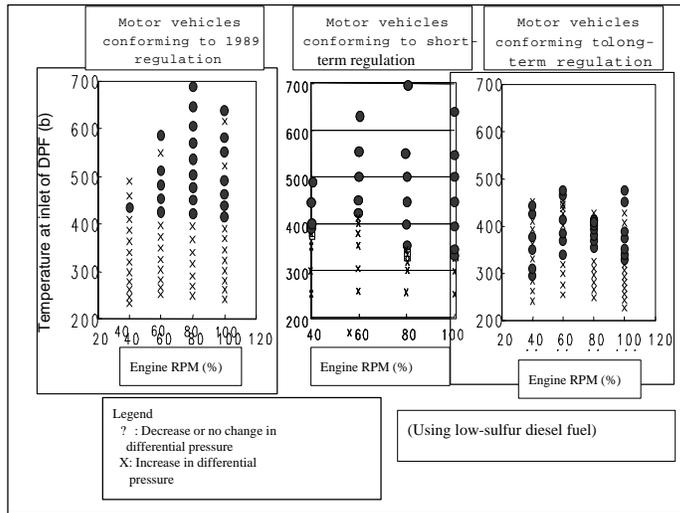
Exhaust Emission Test Results of Continuous Regenerative Type DPF (b)  
 (actual running mode :average speed 53.4 km/h)  
 (using existing diesel fuel)



Difference in Components of PM Between Installing and Not Installing DPF (using existing diesel fuel)

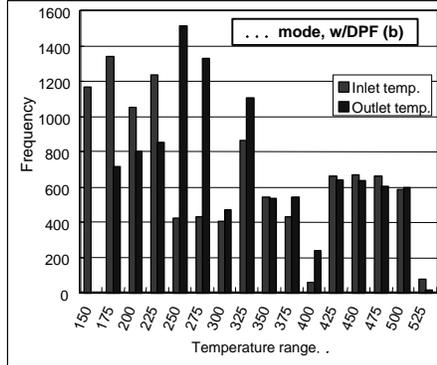


Effects of Installed DPF(b) on the Amount of NO<sub>2</sub> Emissions

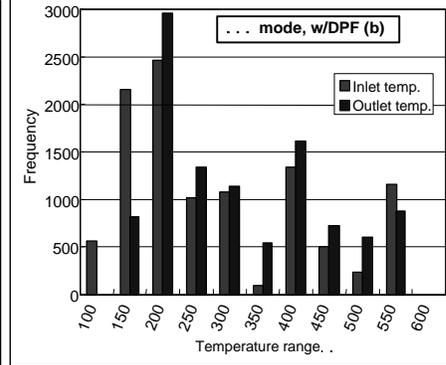


Regeneration Temperature Ranges of DPF(b)  
(using existing diesel fuel)

HINO P11C for 10 ton truck  
 . Conforming to Short-term Regulation.

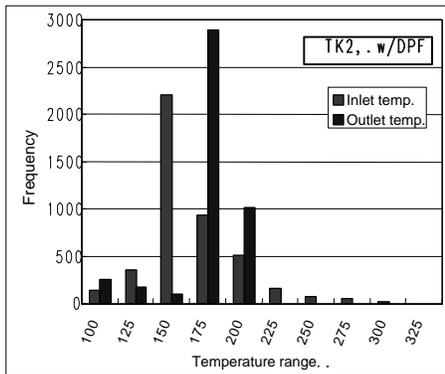


MITUBISHI 6D17 for 4 ton truck  
 . Conforming to Short-term Regulation .

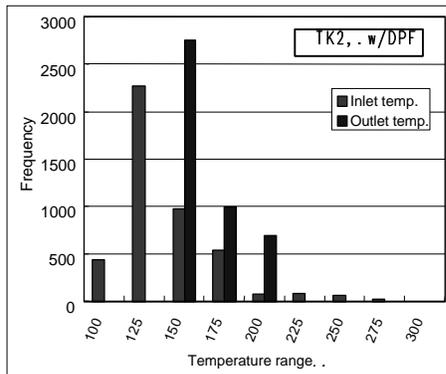


Inlet and outlet temperature distribution of DPF (b)  
 ( Japanese D-13 mode)

HINO P11C for 10 ton truck  
 . Conforming to Short-term Regulation.



MITUBISHI 6D17 for 4 ton truck  
 . Conforming to Short-term Regulation .

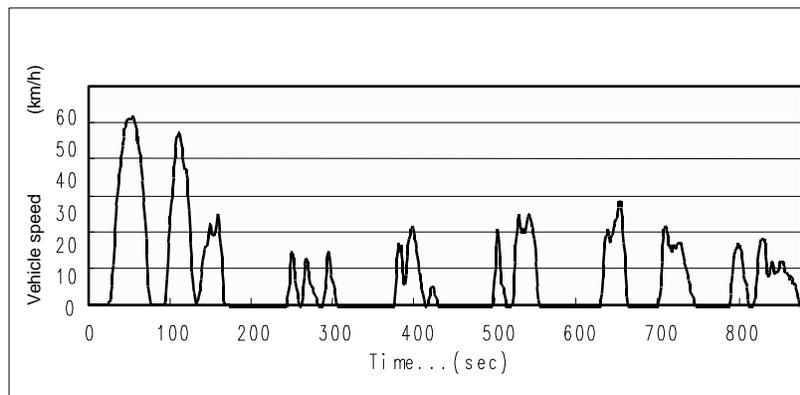


Inlet and outlet temperature distribution of DPF (b)  
 ( TK2 mode: average speed 8.4 km/h)

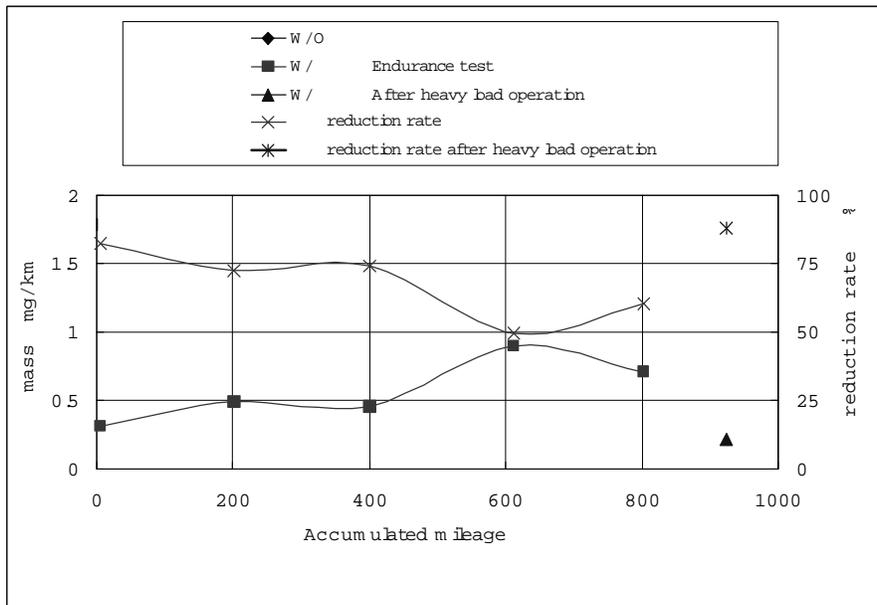
## Endurance test with a truck equipped with DPF (b)

. Start from Feb.2001, accumulated mileage is about 1000 km.

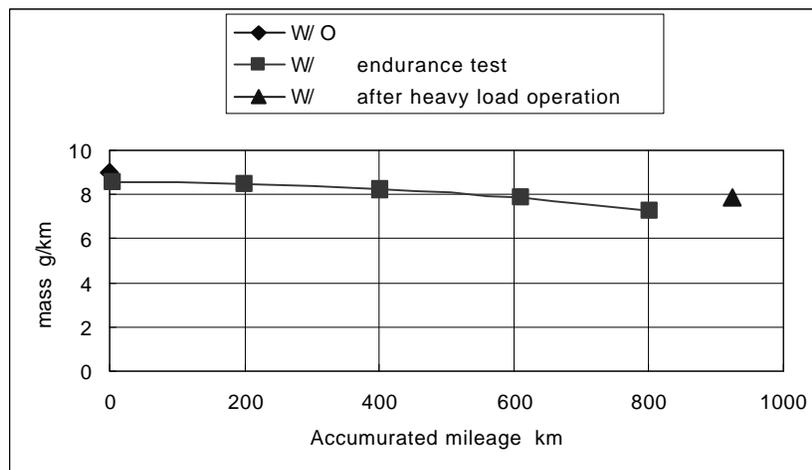
- Tested vehicle:  
Engine displacement 8 L, Conforming to Short-term Regulation
- Tested DPF:  
Continuously regenerating type (Based on oxidation by catalyst)
- Measurement:  
The tested vehicle with the DPF was set on a CH-DY and driven in long hours.  
Exhaust emissions and the regeneration behavior has been observed.
- With repetition of TK2 mode driving, that has low average speed, PM stacking condition and regeneration performance by measuring DPF differential pressure and temperatures.
- The measurements were held every 200km of mileage accumulation.



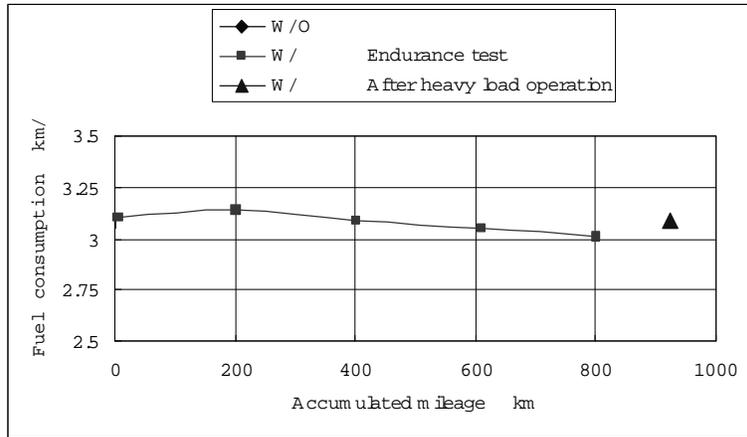
TK2 Driving Pattern (average speed: 8.4 km/h)



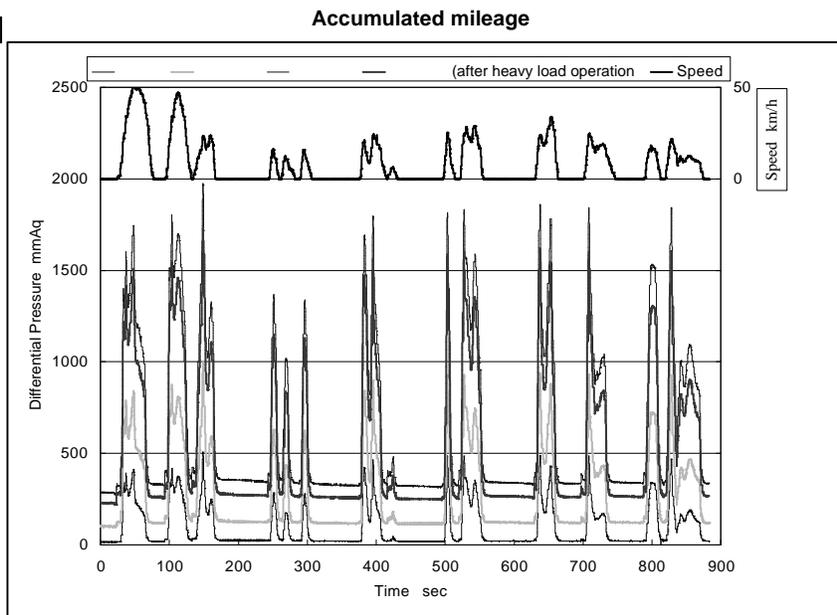
Change of PM mass and PM reduction rate at endurance test



Change of NOx mass at endurance test



Change of fuel consumption at endurance test



Change of DPF differential pressure

## **Examples of Failure during Evaluation Test (1)**

### Tested Vehicle

Tested vehicle specification

Engine displacement	7.961L
Engine type	DI,TCIC
Emission regulation	Long-term Regulation
Net vehicle weight	3810kg
Max freight	5700kg
Gross vehicle weight	9620kg

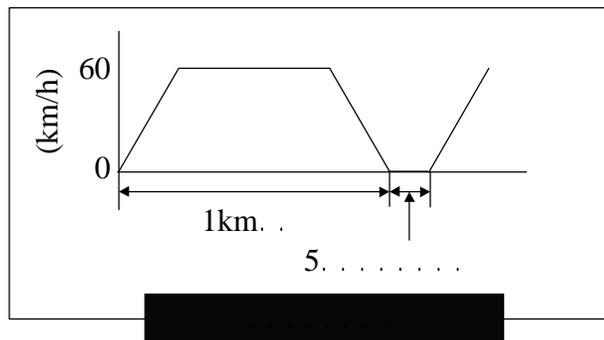
### Tested fuel specification

	Units	No.1		No.2	
		Value	Value	Value	Value
Density at 15°C	g/cm <sup>3</sup>	0.8407	0.8357	0.8311	
PMCC	°C	71.0	69.0	64.5	
Viscosity at 40°C	mm <sup>2</sup> /s	3.926	4.245	3.521	
Flash point	°C	-15.0	-2.5	-12.5	
CFPP	°C	-6	0	-9	
Sulfur content	wppm	41	41	40	
Water content		52.6	54.0	55.8	
Calorific value	kJ/kg				
Net calorific value	kJ/kg	217.0	219.0	196.0	
Gross calorific value	kJ/kg	279.0	288.0	282.0	
Higher calorific value	kJ/kg	329.0	350.0	339.5	

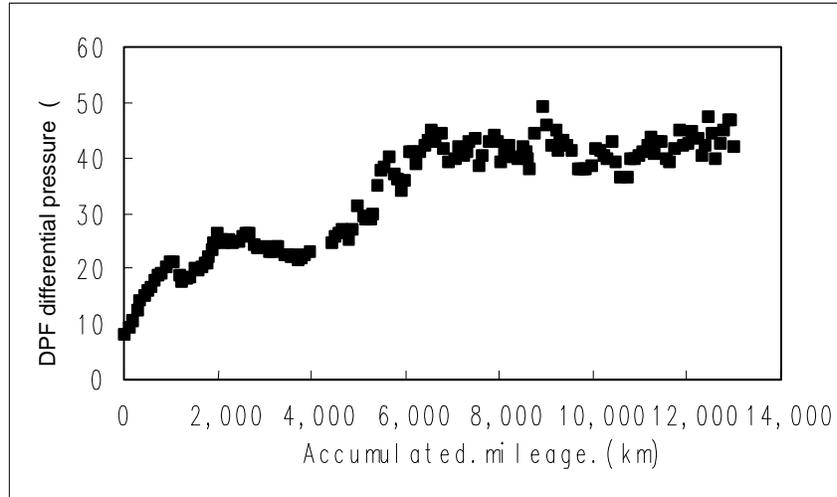
### Driving pattern at endurance test

..... JARI .....

.....



Change of DPF differential pressure (kPa)

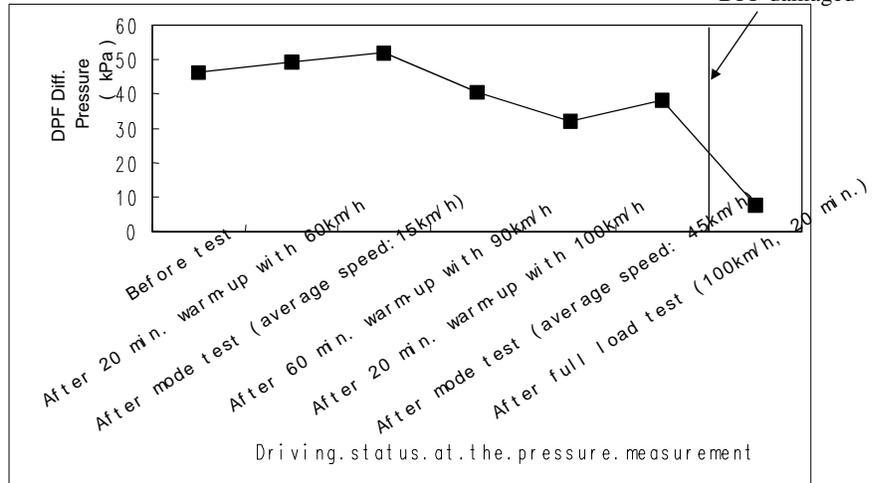


Exhaust emission test results before and after fleet test

..... 13...	..... (g/kWh)			
	CO	THC	NOx	PM
.....	0.00	0.08	4.28	0.036
..... .1.	0.02	0.06	4.44	0.263
..... (.2.	1.13	0.28	4.57	0.213
.....	..... (g/km)			
	CO	THC	NOx	PM
..... 15km/h	0.11	0.01	3.50	0.009
.....	0.04	0.01	3.79	0.018
..... (.2.	1.74	0.51	3.52	0.231
.....	..... (g/km)			
	CO	THC	NOx	PM
..... 45km/h	0.01	0.00	2.18	0.004
.....	0.00	0.00	2.31	0.004
..... (.2.	1.26	0.31	2.40	0.149

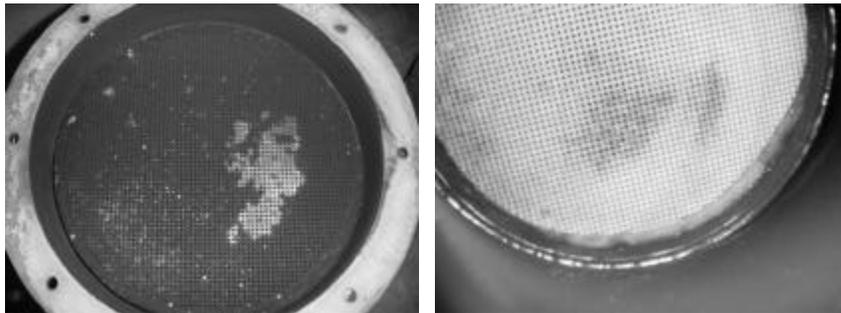
. 1. .... DPF. ....  
 . 2. ....

## Change of DPF differential pressure at driving on a CH-DY after fleet test



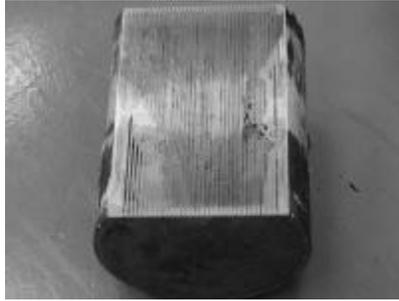
\* Method for measuring DPF differential pressure:  
 Making free acceleration when DPF inlet temp. is 130. and measured DPF differential pressure 5 seconds later.

Inlet of DPF. . . . . Outlet of DPF



DPF condition after the Test

Cross section of  
the DPF



Detail of melting part



**Examples of  
Failure during Evaluation Test (2)**

## Outline of DPF Fleet Test

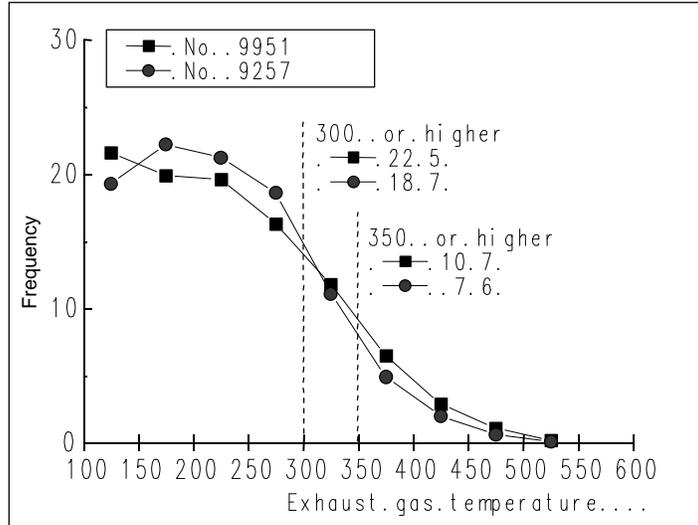
- Two tank truck. 14KL. 16KL.....-ton  
... Continuous measurement of exhaust temp.  
and back pressure
- Performance evaluation: by watching of  
free accel. smoke

Car No.	Manufacturer	Model	Model year	Emission Regulation	Engine type	Displacement	Max. Power	Max. torque
						L	PS/rpm	kgm/rpm
9951	ISUZU	KC-CYG23P1	H8	Short-term	6SD1	9.83	310/2200	130/1300
9257	NISSAN DIESEL	U-CV450MN (modified)	H4	1989	PF6	12.5	330/2100	142/1200
Both vehicles are D with T/I and MT								

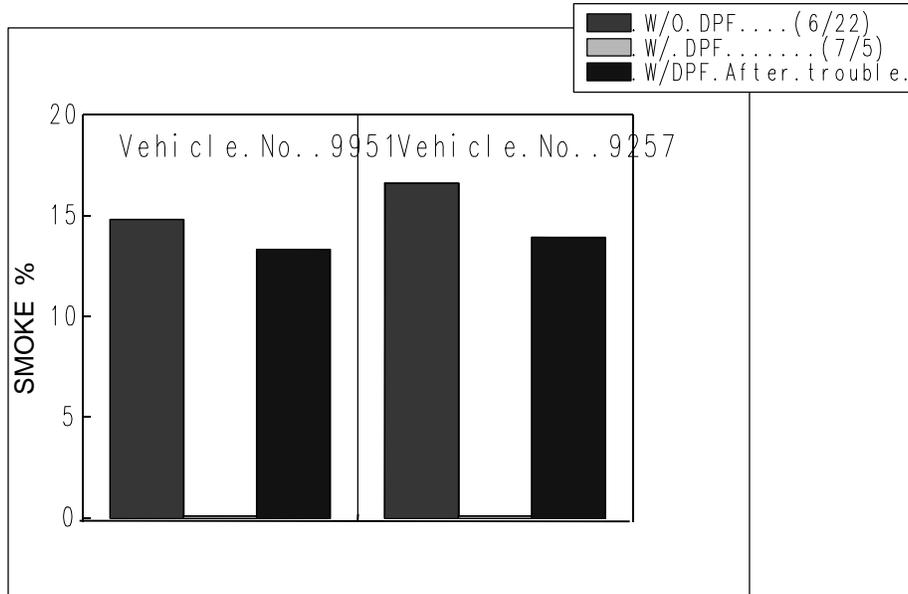
## Progress of fleet test

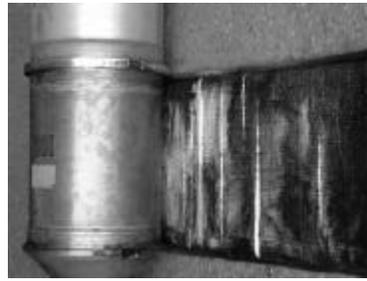
- 6/27. Fleet test start
- 6/27. 8/2. No trouble both test vehicles
- 8/3. 8/16. . Trouble?.
- 8/17. Identify a trouble in both vehicles
- 9/12. Remove DPF, test finished
- . . \*Send DP. to the manufacturer for inspection

### Comparison of exhaust temperatures between vehicles



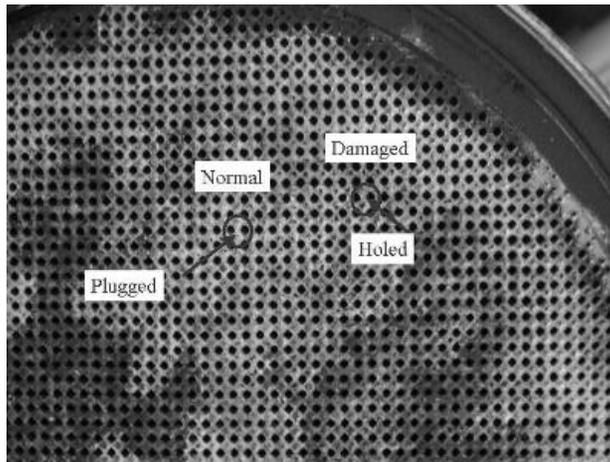
### Smoke Measurement Result





Many leak of Soot at Housing Cramp

Detail of CSF Trouble (1)



. Plugging of Honeycomb is damaged at some region

Detail of CSF Trouble (2)

## Opinion of the Manufacturer

- Time was limited and they could not have enough time to design and supply new type DPF suitable for Japanese Market.

- . New Type . Capacity 30. . ,BPT50. . .
- . Exhaust flow was not uniform.
- . Lack of understanding for emission level of Japanese vehicles.

- Performance of continuous regeneration was not functioning well due to lower exhaust temperature.
- Inside Melting of DPF by abnormal combustion of stacked soot.

## Conclusion

### **Policy of Japanese Government for Diesel Retrofit**

- Replacement of in-use diesel vehicles with vehicles that comply with new regulations is the most appropriate measure.
- It is impossible to require retrofitting of DPFs on all vehicles. Yet, on those vehicles to which DPFs can be attached, they have proven to be effective in reducing emissions.
- The government started rule making of DPF technical guideline which should be cleared for Diesel Retrofit Verification.
- The government makes financial support (Subsidy) to public transportation organizations such as city buses which are introducing effective retrofit system by voluntary basis. Total amount of the subsidy in 2001 is 200million yen (\$1.6 million).